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(54) Photosensor array with multiple different sensor areas

(57) A photosensor array has at least one row of photosensors (100, 102, 104) (200, 202, 204) with a first sensor size, and at least one row of photosensors (106) (206, 208, 210) with a second sensor size, with the two sizes being different. In a first example embodiment, each sensor in a row of sensors for white light (106) (206, 208, 210) has a smaller area than the sensors in other rows. For the first embodiment (figure 1), the native input sampling rate for luminance is greater than the native input sampling rate for color information. In a second example embodiment (figure 2), for every band of wavelengths being sensed, there are two rows of sensors, with one row having relatively small sensor areas and the other row having relatively large sensor areas. In the second example embodiment, the rows with relatively small sensor areas are used for high native input sampling rates, and the rows with relatively large sensor areas are used for high color accuracy.

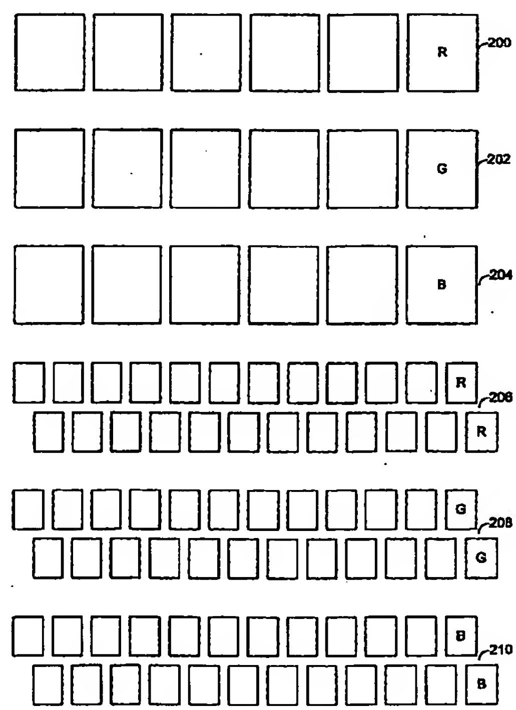

FIG. 2

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Description

FIELD OF INVENTION

[0001] This invention relates generally to photosensor arrays used for optical image scanners and cameras and more specifically to line arrays commonly used for optical image scanners.

BACKGROUND OF THE INVENTION

[0002] Image scanners convert a visible image on a document or photograph, or an image in a transparent medium, into an electronic form suitable for copying, storing or processing by a computer. An image scanner may be a separate device or an image scanner may be a part of a copier, part of a facsimile machine, or part of a multipurpose device. Reflective image scanners typically have a controlled source of light, and light is reflected off the surface of a document, through an optics system, and onto an array of photosensitive devices. The photosensitive devices convert received light intensity into an electronic signal. Transparency image scanners pass light through a transparent image, for example a photographic positive slide, through an optics system, and then onto an array of photosensitive devices.

[0003] Photosensor arrays commonly have three or four rows of sensors, with each row receiving a different band of wavelengths of light, for example, red, green and blue. Each row may be filtered, or white light may be separated into different bands of wavelengths by a beam splitter. Typically, the pitch (spacing of individual photosensor elements) is the same for each row, and typically the pitch is set to provide a specified native input sampling rate.

[0004] In general, there is an ongoing demand for increased resolution and speed, improved color quality and image quality, and reduced cost, demands that often directly conflict and require trade-offs. The following background presents some of the factors affecting resolution, speed, color quality, image quality and cost.

[0005] In general, image scanners use an optical lens system to focus an image onto an array of photosensors. Photosensor arrays typically have thousands of individual photosensitive elements. Each photosensitive element, in conjunction with the scanner optics system, measures light intensity from an effective area on the document defining a picture element (pixel) on the image being scanned. Optical sampling rate is often expressed as pixels per inch (or mm) as measured on the document (or object, or transparency) being scanned. Optical sampling rate as measured on the document being scanned is also called the input sampling rate. The native input sampling rate is determined by the optics and the pitch of the individual sensors. A scanner operator may select a sampling rate that is less than the native input sampling rate by simply dropping selected pixels, or by using digital resampling techniques. Alternatively, a scanner operator may select a sampling rate that is greater than the native input sampling rate where intermediate values are computed by interpolation. Typically, all the charges or voltages are read from the photosensor array, and are then digitized, and then subsampling or interpolation is performed on the resulting digital pixel data.

[0006] Bit depth is the number of bits captured per pixel. Typically, a pixel is specified in a three-dimensional color space with a fixed number of bits in each dimension. For example, a pixel may be specified in red, green, blue (RGB) color space, with 8 bits of red information, 8 bits of green information, and 8 bits of blue information, for a total of 24 bits per pixel. Alternatively, a pixel may be specified in a cylindrical color space in which the dimensions are luminance, chrominance, and saturation. Alternatively, a three-dimensional CIE color space may be used, for example, CIELAB or CIELUV, where one dimension is luminance. In this application, "high" bit depth means that all bits are accurate, distinguishing accuracy from simple resolution. That is, a scanner could provide many bits of information, but have a noise level that makes most of the lower order bits meaningless.

[0007] Even if a sensor is receiving no light, some thermal noise (called dark noise) may occur. Thermal noise (dark noise) is proportional to time. During exposure to light, the primary noise source (called shot noise) is related to conversion of photons to electrons, and the noise increases with the square root of the signal. Small sensors tend to have a lower signal-to-noise ratio than large sensors, particularly for low reflectance or low transmissivity areas of a document. Smaller sensor areas can provide higher input sampling rates, but other measures of image quality, and in particular color quality, as measured by signal-to-noise, may be reduced.

[0008] If an input sampling rate is selected that is lower than the native input sampling rate, then the signal-to-noise may be improved by averaging samples. Analog signals from adjacent sensor areas may be added, or digital values may be averaged after analog-to-digital conversion. Adding N samples improves the signal-to-noise ratio by the square root of N. Typically, adding analog signals requires the signal levels to be relatively small before adding to avoid saturating a charge element, so that analog averaging is typically used for speed (fewer shifts) but not for improvement in signal-to-noise ratio.

[0009] Scanning speed is affected by multiple factors: exposure time, shift time of registers multiplied by number of pixels being shifted, and output amplifier speed. Typically, for low native input sampling rates, the primary limiter is exposure time, that is, the time required to generate a signal that provides an acceptable signal- to-noise ratio. However, if the number of pixels being shifted becomes very large, then the time

required to shift the individual pixel signals to an amplifier may become the limiting factor.

[0010] Areas of an image with slowly varying color, particularly dark colors, require high bit depth and high signal-to-noise to accurately reproduce the smooth tone and texture of the original. For areas of slowly varying color, high input sampling rate is not needed because there is no high frequency information in the image. Areas of an image that change color rapidly, for example a forest scene, or a close-up photograph of a multicolored fabric, need a high input sampling rate to capture the high frequency information, but high bit depth and high signal-to-noise are not needed. That is, for high frequency information, the color accuracy of each individual pixel is less important. High input sampling rates require small sensor areas, which in turn have relatively low signal-to-noise ratios, relatively low bit depth, and relatively low scanning speed. Large sensor areas provide high signal-to-noise, high bit depth, and high speed, but cannot provide high input sampling rates.

[0011] There is a need for a scanner that provides both high color quality and high native input sampling rate.

SUMMARY OF THE INVENTION

[0012] A photosensor array has at least one line of photosensors with a first sensor size, and at least one line of photosensors with a second sensor size, with the two sizes being different. In a first example embodiment, each sensor in a line of sensors for white light has a smaller area than the sensors in other lines. For the first embodiment, the native input sampling rite for luminance is greater than the native input sampling rate for chrominance and saturation. In a second example embodiment, for every band of wavelengths being sensed, there are two lines of sensors, with one line having relatively small sensor areas and the other line having relatively large sensor areas. In the second example embodiment, the lines with relatively small sensor areas are used for high native input sampling rates, and the lines with relatively large sensor areas are used for high color accuracy and speed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

Figure 1 is block diagram plan view of a multi-row photosensor array in accordance with a first example embodiment of the invention.

Figure 2 is a block diagram plan view of a multi-row photosensor array in accordance with a second example embodiment of the invention

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

[0014] Figure 1 illustrates a photosensor array with three rows having relatively large sensor areas (100, 102, and 104) plus one double row having relatively small sensor areas (106). The area of each sensor element in rows 100-104 is illustrated as being approximately four times the area of each sensor element in double row 106 (which will be discussed in more detail later below). Sensor areas 106 may optionally be in a staggered double row as illustrated, may optionally be overlapping as illustrated, or may optionally be non-overlapping. However, for purposes of the present invention, the important feature of sensor areas 106 is size, and not whether they are arranged in a double row, or overlapping, or non-overlapping. For convenience of discussion, small CCD's requiring a focusing lens will be used to illustrate certain points. For convenience of illustration, each single row (100-104) in figure 1 illustrates 6 sensors, and the double row (106) illustrates 24 sensors, whereas in an actual photosensor array used in scanning each row might have several thousand sensors.

[0015] For convenience of discussion, assume, for example, that row 100 receives red light, row 102 receives green light, row 104 receives blue light, and double row 106 receives visible white light (double row 106 may have a filter that suppresses infrared light). The actual order of color is not important and the ordering illustrated is only an example to facilitate discussion. Note that the exposure time may be different for each sensor size to enable each sensor to generate sufficient electrons to provide a specified signal level at a specified maximum illumination intensity on the document being scanned, even though filter transmissivity or beam splitting efficiency may vary from color to color.

[0016] Consider, for example, typical prior art sensor arrays. For the first example, consider an array having three lines having the sensor areas of rows 100-104 of figure 1. For a second example, consider an array having three double rows having the sensor areas of double row 106 of figure 1. The first example array provides good signal-to-noise but at a relatively low native input sampling rate. The second example array provides a high native input sampling rate, but with reduced signal-to-noise, and may provide more data than is actually needed. That is, for the second example array, the high input sampling rate may not be needed for red and blue.

[0017] Of course, for the second example, one could average the data from sets of four sensor areas to generate approximately the native input sampling rate of the first example. However, note that a sensor area having four times the area will have at least two times better signal-to-noise, whereas averaging four samples, because of smaller signals, A/D conversion, and other factors, will improve the signal-to-noise by less than a factor of two. In addition, averaging digitized signals

adds complexity and requires time. In addition, four of the sensors in double row 106 have less active area than one sensor in a single row (100-104) because of the fixed size of non-sensitive areas. As illustrated in figure 1, the spacing between sensor areas for double row 106 must be about the same as the spacing between sensor areas for rows 100-104. For the specific example of figure 1, if the horizontal space between sensor areas in rows 100-104 is one unit, the sensor areas in rows 100-104 are drawn as 7 units wide by 8 units high, and the sensor areas in double row 106 are drawn as 3 units wide by 4 units high. As a result, the sum of four areas from double row 106, given the sizes chosen for figure 1, is 48/56 or about 86% of the area of one sensor area from rows 100-104. Therefore, for the two examples, even for the same input sampling rates, the first example provides better signal-to-noise than the second example.

[0018] The sensor array of figure 1 provides the advantages of both examples, providing a high input sampling rate at a relatively low signal-to-noise ratio for luminance, which carries most of the high frequency information, and a high signal-to-noise at a lower sampling rate for color, where bit depth is important. If row 106 receives visible white light, as assumed above for illustration, then the array of figure 1 provides luminance information at four times the native input sampling rate of red, or green, or blue. However, the red, green, and blue channels provide better signal-to-noise, permitting more accurate bit depth to enable resolution of small incremental steps of intensity. The red, green, and blue data may, for example, be transformed into a CIELAB or CIELUV color space, and then the luminance data from the double row may be used for the luminance dimension instead of the luminance data from the red, green, and blue sensors.

[0019] Figure 2 illustrates an alternative example embodiment of the invention. In figure 2, a sensor array has one row of relatively large sensors for each of three colors (200, 202, and 204), and one double row of relatively small sensors for each of three colors (206, 208, 210). If a scanner operator chooses a high input sampling rate, the double rows (206, 208, 210) may be used. If the scanner operator chooses a low input sampling rate, the single rows (200, 202, 204) may be used.

[0020] All rows in figure 2 may receive a limited bandwidth of wavelengths, for example, red, green and blue as illustrated. Again, the order of the colors is just an example. Alternatively, one single row and one double row may receive white light, and one color may be computed. For example, if the rows receive red, blue and white, green may be computed as: green = white - (red + blue) . If one single row and one double row are white, then combinations of sizes may be used for one scan as discussed for figure 1. In addition, if one single row and one double row are white, then black and white scans (for example, text or line art) may be performed using only a white channel, which in general is faster. That is, comparing a high resolution white channel (figure 1, 106) to the same resolution color channel (figure 2, 206), the white channel receives unfiltered higher intensity light, and is therefore faster (See, for example, U.S. Patent Number 5,773,814). Finally, large sensors require less exposure time than small sensors, so that the row of large sensors may be used alone for faster scans.

[0021] The embodiment of figure 2 provides high resolution for all colors, or high signal-to-noise for all colors, depending on the needs of the scanner operator. The embodiment of figure 2 may require more amplifiers (6 amplifiers for figure 2 versus 4 amplifiers for figure 1). However, signals may be multiplexed so that, for example, in figure 2, row 200 may share an amplifier with row 206, row 202 may share an amplifier with row 208, and row 214 may share an amplifier with row 210, requiring only three amplifiers and three multiplexers. For some applications, the embodiment of figure 1 may provide suitable input sampling rate and signal-to-noise at a slightly lower cost than the embodiment of figure 2. If the embodiment of figure 1 has a high-resolution white channel as illustrated, and if the embodiment of figure 2 has all color channels as illustrated, then the embodiment of figure 1 also has the advantage of faster black and white scans, as discussed above. Either embodiment provides either higher input sampling rate, or higher signal to noise, relative to a sensor array that only has sensor areas of one size.

[0022] The photosensor arrays illustrated in figures 1 and 2 may comprise, for example, CCD's, CMOS sensors, photodiodes, solar cells, or other sensors suitable for converting light intensity into an electrical signal. The photosensor arrays illustrated in figures 1 and 2 may alternatively comprise Contact Imaging Sensors (CIS), which may also use CCD's or CMOS or other technologies. Note that CIS modules typically do not use filters or beam splitters, but instead, use a single sensor row and sequentially illuminate the row with different colored light sources, such as Red, Green, and Blue Light Emitting Diodes (LED's). Therefore, for CIS modules, the configuration could comprise a single row having relatively large sensor areas, and a single row having relatively small sensor areas, with no color filtering on either row. Both rows may be used simultaneously, using the small sensors for a high-input-sampling-rate, high-noise luminance channel and the larger sensors for low-input-sampling rate, low-noise color. One row may be used. That is, the row with relatively small sensor areas may be used for high native input sampling rates, or the row with relatively large sensor areas may be used for high color accuracy. Alternatively, the row with large sensors may be used alone for faster scanning.

[0023] The foregoing description of the present invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and other modifications and variations may be possible in

light of the above teachings. The embodiment was chosen and described in order to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilize the invention in various embodiments and various modifications as are suited to the particular use contemplated. It is intended that the appended claims be construed to include other alternative embodiments of the invention except insofar as limited by the prior art.

Claims

1. A photosensor array, comprising:

   at least one row of first photosensors (100, 102, 104) (200, 202, 204), each first photosensor having a first active area;
   at least one row of second photosensors (106) (206, 208, 210), each second photosensor having a second active area; and
   the first active area being not equal to the second active area.

2. The photosensor array of claim 1, further comprising:

   the first active area being larger than the second active area.

3. The photosensor array of claim 2, further comprising:

   each of the first and second active areas receiving light having a bandwidth of wavelengths that is less than the bandwidth of wavelengths of human visible light.

4. The photosensor array of claim 2, further comprising:

   each first active area receiving light having a bandwidth of wavelengths that is less than the bandwidth of wavelengths of human visible light; and
   each second active area receiving light having a bandwidth of wavelengths that is at least as great as the bandwidth of wavelengths of human visible light.

5. A method of scanning, comprising the following steps:

   receiving light, by at least one row of first photosensors (100, 102, 104) (200, 202, 204), each first photosensor having a first active area;
   receiving light, by at least one row of second photosensors (106) (206, 208, 210), each second photosensor having a second active area, the second active area being smaller than the first active area;
   using intensity measurements from the row of first photosensors for high signal-to-noise image data; and
   using intensity measurements from the row of second photosensors for high input sampling rate image data.

6. A method as in claim 5, further comprising the following step:

   using intensity measurements from the row of first photosensors for high speed scanning.

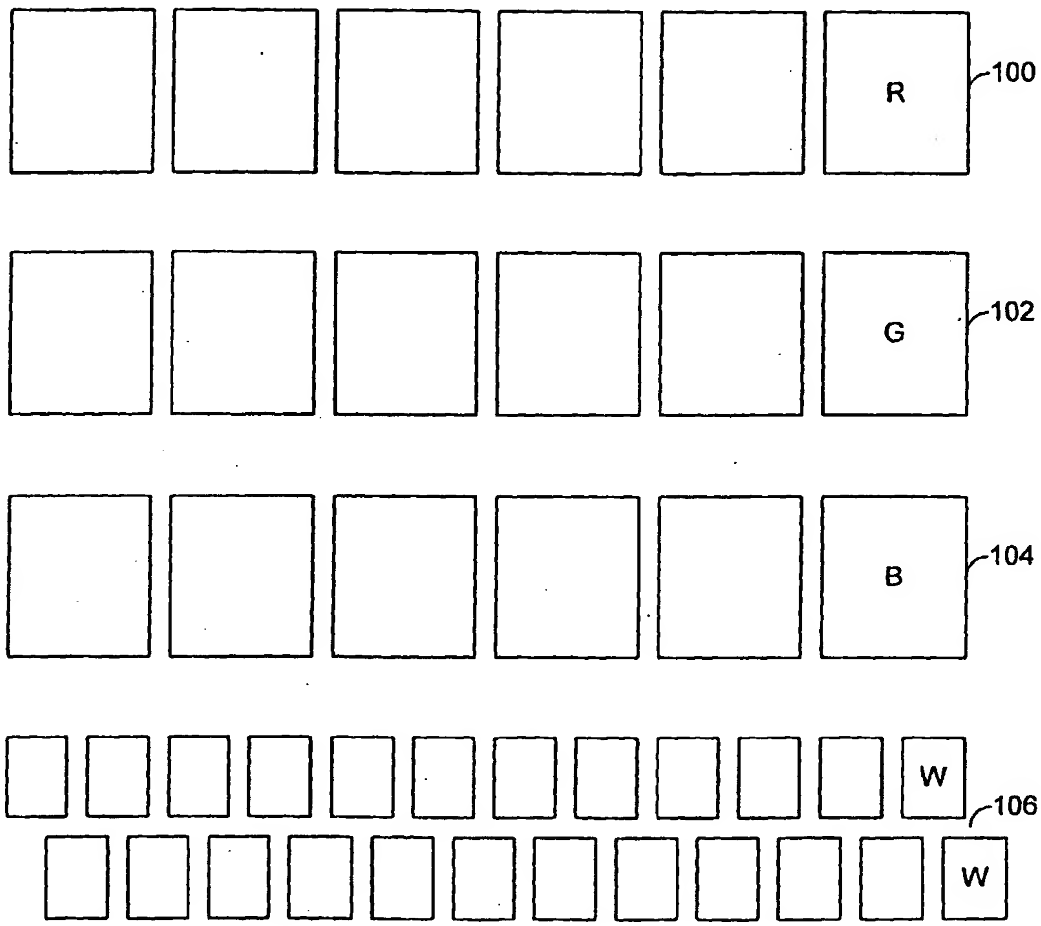

FIG. 1

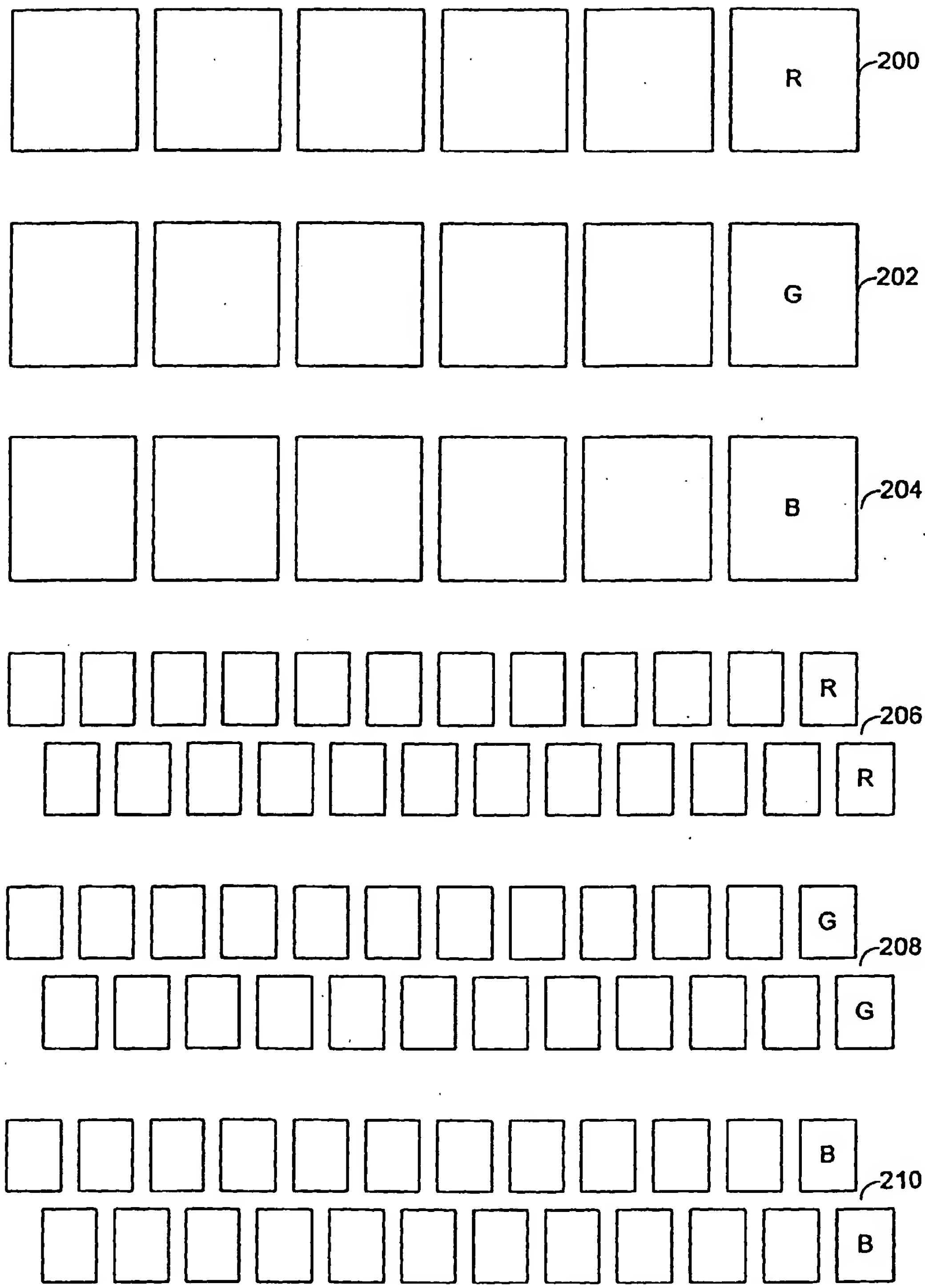

FIG. 2

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(54) **Photosensor array with multiple different sensor areas**

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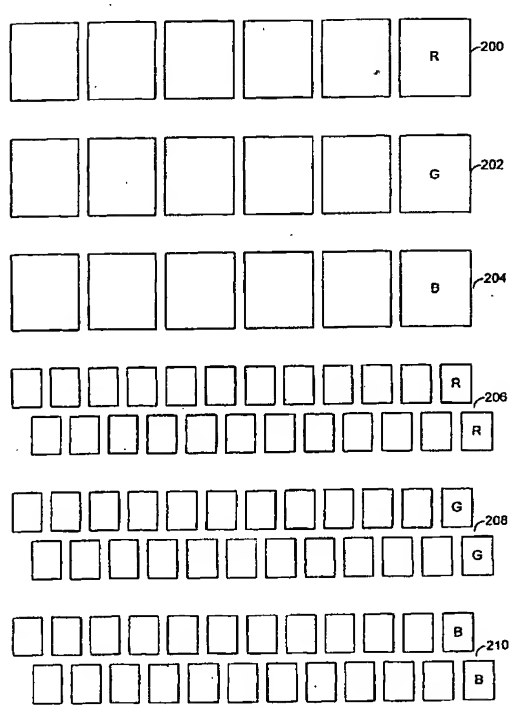

FIG. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 00 11 2167

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 5 045 932 A (SHARMAN RICHARD A ET AL) 3 September 1991 (1991-09-03) * column 4, line 46 - column 6, line 60; figure 3 *	1,2,4,5	H04N1/48 H04N3/15 H04N1/04
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	1 December 2003	Seytter, F

CATEGORY OF CITED DOCUMENTS

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